PROTOCOL
FOR
MONITORING EFFECTIVENESS
OF
CONSTRAINED CHANNELS

(Dike Removal/Setback, Riprap Removal, Road Removal/Setback, and Landfill Removal)

MC-5

Washington Salmon Recovery Funding Board

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Prepared by
Bruce Crawford
Project Manager

Laura E. Johnson, Director

Interagency Committee for Outdoor Recreation
1111 Washington Street
PO Box 40917
Olympia, Washington
98504-0917

www.iac.wa.gov

TABLE OF CONTENTS

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ORGANIZATION

This document details the monitoring design, procedures, and quality assurance steps necessary to document and report the effectiveness of stream bank modifications addressing constrained channels:

- **Dike Removal/Setback**
- **Riprap Removal**
- **Road Removal/Setback**
- **Landfill Removal**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002).

Diking, road construction, fills, and other construction work within the stream's normal flood line can constrain flow within the normal flow channel leading to scouring effects upon stream gravel, loss of hiding cover and food organisms, and unsuitable habitat for rearing juvenile salmon. Unconstrained streams dissipate flood flow energy over a broader valley floor and provide slower velocities for preserving stream channel morphology and rearing habitat for salmon.

The goal of constrained channel projects is to restore the natural flood flow basin width so that gravel, large wood, and normal stream morphology and fish habitat can be restored.

MONITORING GOAL

Determine whether projects that remove or set back dikes, riprap, roads, or landfills are effective at the reach scale in restoring stream morphology and eliminating channel constraints in the treated area.

QUESTIONS TO BE ANSWERED

Has removal and/or setback reduced channel constraints and increased flood flow capacity for ten years?

Has stream morphology improved over ten years?

NULL HYPOTHESIS

Removal or setback of dikes, riprap, roads, or landfills or reconnected side channels along the stream has had no significant affect upon:

- Improving channel capacity.
- Improving stream morphology and fish habitat as measured by Thalweg residual pool vertical profile area (AREASUM) and mean residual depth (RP100).

OBJECTIVES

BEFORE PROJECT OBJECTIVES (YEAR 0)

Determine the overall channel capacity and constraints in the impact area.
Determine the overall stream morphology using Thalweg Profile in the impact area.

AFTER PROJECT OBJECTIVES (YEARS 1, 3, 5, AND 10)

Determine the overall changes in channel constraints and flow capacity in the impact area.
Determine the overall stream morphology using Thalweg Profile in the impact area.

RESPONSE INDICATORS

Level 1 --Channel capacity as cross-sectional area calculated from mean bankfull width (XBF_W) and height (XBF_H) measures the overall channel flow capacity. When a channel is constrained the velocity of the water increases to compensate for higher volume. Increased velocity scours stream bottom eliminating pools, large wood, and other structures associated with fish habitat.

Indicator Abbreviation	Description
XBF_H	Mean bankfull height within the study reach
XBF_W	Mean bankfull width within the study reach

Level 2--Thalweg Profile. The Thalweg Profile characterizes pool-riffle relationships, sediment deposits, wetted width substrate characteristics, and channel unit-pool forming categories. Stream morphology sampling methods are taken from EMAP (Peck et al. unpubl.), Section 7.4. Protocols summarizing EMAP Table 7-3 and 7-4 are found on page 12. Sampling is based upon establishing 11 regular transects within each identified stream reach. Pre-project measures of the variation of depth throughout the stream reach (RP100) and the residual pool volume (AREASUM) will be compared to detect post-project changes.

Thalweg indicators for constrained channels.

Indicator Abbreviation	Description
AREASUM	Mean Thalweg vertical profile area for the study reach
RP100	Mean Thalweg residual depth within the study reach
CHANL	Study reach bankfull channel capacity

MONITORING DESIGN

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with restoring constrained channels (Stewart-Oaten et al.1986). A BACI design samples the control and impact simultaneously at both locations at designated times before and after the impact has occurred. For this type of restoration, removing a channel constraint would be the impact, that is, the location impacted by the restoration action, and a location upstream of the constrained channel would represent the control.

For constrained channels, the BACI design tests for changes in channel capacity in terms of cross sectional area and stream morphology at the constrained channel location *relative to* the changes in stream morphology and channel capacity observed at a control site upstream. This type of design is required when external factors (e.g., local watershed characteristics) affect the flood flow events at the control sites. The object is to see whether the difference between upstream (control) and downstream (impact) channel capacity in terms of cross sectional area and stream morphology has changed as a result of the channel constraint projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplications. It is also not considered cost effective to employ multiple control locations for each passage project as recommended by Underwood. Although the ideal BACI would have multiple years of before data as well as after data, this was not possible with locally sponsored projects where there is a need and desire to complete their project as soon as possible.

The plan is to compare the most recent time period of sampling with Year 0 conditions before the projects. A paired *t*-test will be used to test for differences between control (upstream) and impact (downstream) sites during the most recent impact year and Year 0. In other words, we first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact sites are only affected by the placing of constrained channels and that external influences affect channel capacity in terms of cross-sectional area and stream morphology in the same way at both the control and impact sites. The paired sample *t*-test does not have the same assumptions for normality and equality of variances of the two-sample *t*-test but only requires that the differences are approximately normally distributed. In fact, the paired-sample test is really equivalent to a one-sample *t*-test for a difference from a specified mean value.

To implement the design, beginning in 2004 we will monitor 10 constrained channels projects funded in Rounds 4-6. The number of projects proposed for funding in each category will be based upon the calculated sample size needed to obtain statistically significant information in the shortest amount of time. Because there are insufficient projects funded in any one year to obtain a proper sample size, multiple years will be used until the critical sample size is reached.

The variance associated with impact and control areas will not be known until sampling has occurred in Year 0 of both impact and control areas. After Year 0, a better estimate of the true sample size needed to detect change will be available. Cost estimates and sampling replicates may need to be adjusted at that time.

At the end of the effectiveness monitoring testing, there will be one year of “Before” impact information for all projects for both control and impact areas, and multiple years of “After” impact information for the same control and impact areas for each of the projects.

Depending upon circumstances, the results may also be tested for significance, using a linear regression model of the data points for each of the years sampled and for each of the indicators tested.

Testing for significant trends can begin as early as Year 1. Final sampling may be completed in 2014.

DECISION CRITERIA

Effective if a change of 20% or more is not detected for channel capacity between the calculated difference between the paired impact and control areas by Year 10 at the α=0.10 level.

Effective if a change of 20% or more is detected for Thalweg measures of residual pool vertical profile area (AREASUM) and mean residual depth (RP100) between the calculated difference between the paired impact and control areas by Year 10 at the α =0.10 level.

Table 1. Decision criteria for testing constrained channels.

Indicators	Metric	Test Type	Decision Criteria
Mean bank full cross sectional area taken from mean bank full width and height (CHANL)	Ave. m^2	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Effective if it does not detect a 20% or greater change between Year 0 and Year 10.
Mean residual pool vertical profile area (AREASUM)	m^2	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10.
Mean residual depth (RP100)	cm	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Base Year 0 and Year 10

SAMPLING

SELECTING SAMPLING REACHES

IMPACT AREAS

Channel constraint projects are often not very large and may be measured in their entirety, or may require only one stream reach identified, according to the methods on page 9.

CONTROL AREAS

An equal number of control reaches upstream of the project site should be selected and designed in the same manner as the impact reaches. If there is only one impact reach, then the control should consist of a distance of equal size immediately upstream of the project site.

BEFORE PROJECT SAMPLING

All channel constraint projects identified for long-term monitoring by the SRFB must have completed pre-project Year 0 monitoring prior to beginning the project.

Year 0 monitoring will consist of:

- Determining the extent and capacity of constrained channel due to the dike, etc., in the impact and control areas.
- Determining the stream morphology characteristics within the project impact and control areas using Thalweg Profile.

AFTER PROJECT SAMPLING

Upon completion of the project, Years 1, 3, 5, and 10 monitoring will consist of:

- Determining the extent and capacity of the constrained channel due to removal of the dike, reconnecting the side channel, etc., in the impact and control areas.
- Measuring instream morphology and structure using the Thalweg Profile within the project impact and control areas.

METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS

Protocol taken from: ***Peck et al. (Unpubl.), pp. 63-65, Table 4-4; Mebane et al. (2003)***

EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar painted bright orange, engineer flagging tape, waterproof markers

SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These “impact” areas have been matched with “control” areas of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas. The transects are then averaged to obtain an average representation of the stream reach.

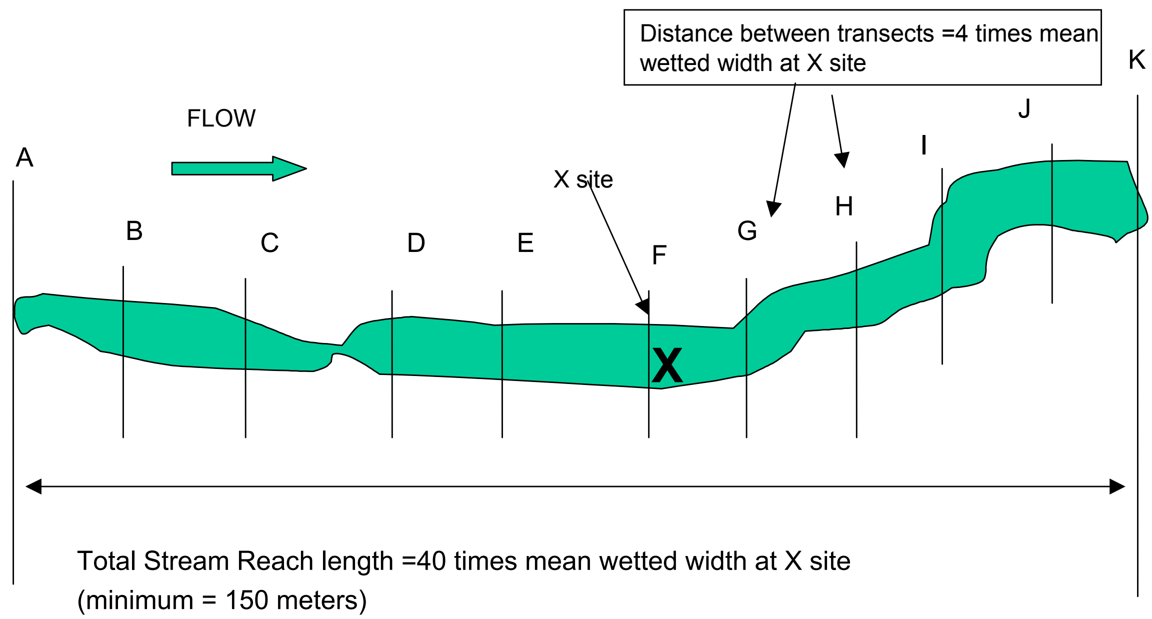


Figure 1. Sampled project reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the **X sites** and record latitude and longitude of same on waterproof sheets. The X sites should be considered the center of the impact and control study reach. The impact reach X site must fall within the project affected area. The location of the control X site should be determined based upon the project category and associated procedure (MC-1 to MC-10). Mark the X site on the bank above the high water mark with one of the rebar stakes so that the X site can be found in future years. Use a surveyor's rod or tape measure to determine the wetted width of the channel at five places considered to be of "typical" width within approximately five channel widths upstream and downstream of the X site sample reach location. For streams less than 4 m in width the reach should be at minimum 150 m.

Step 2: Check the condition of the stream upstream and downstream of the X site by having one team member go upstream and one downstream. Each person proceeds until they can see the stream to a distance of 20 times the stream width (equal to one half the sampling reach length) determined in Step 1.

For example if the reach length is determined to be 150 m, each person would proceed 75 m from the X site to lay out the reach boundaries.

NOTE: *For restoration projects less than 40 stream widths, the entire project's length should be sampled and a control area of similar size should likewise be developed within the treatment stream either upstream or downstream as appropriate.*

Step 3: Determine if the reach needs to be adjusted around the X site due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankins and Reeves (1988) have shown that measures of the variance of juvenile fish populations is decreased by using whole pool/riffles in the sample area.

Step 4: Starting back at the X site, measure a distance of **20 channel widths** down one side of the stream using a tape measure. Be careful not to cut corners. Enter the channel to make measurements only when necessary to avoid disturbing the stream channel prior to sampling activities. This endpoint is the downstream end of the reach and is flagged as transect "A".

Step 5: Using the tape, measure 1/10th (4 channel widths in big streams or 15 m in small streams) of the required stream length upstream from the start point (transect A). Flag this spot as the next cross section or transect (transect B).

Step 6: Proceed upstream with the tape measure and flag the positions of nine additional transects (labeled "C" through "K" as you move upstream) at intervals equal to 1/10th of the reach length.

METHOD FOR MEASURING CHANNEL CONSTRAINTS

Protocol taken from: ***Peck et al. (Unpubl.), Table 7-6; Kauffman et al. (1999)***

PURPOSE

The activities of man often constrain channels by placing roads, dikes, etc. near the streambank. This in turn increases channel velocity during high flow event and causes scouring and loss of fish habitat. The purpose of this protocol is to determine whether the channel constraints have been reduced.

EQUIPMENT

Appropriate waterproof sampling form, waders or hip boots, 50 m measuring tape.

SITE SELECTION

The sample reaches are those laid out according to page 9.

PROCEDURE

Note: *These activities are conducted after completing the Thalweg Profile and represent an evaluation of the entire stream reach.*

Channel Constraint: Determining the degree, extent, and type of channel constraint is based on envisioning the stream at bankful flow.

Step 1: Classify the stream reach channel pattern as predominantly a single channel, an anastomosing channel, or an abraided channel.

- Anastomosing channels have relatively long major and minor channels branching and rejoining in a complex network.
- Braided channels also have multiple branching and rejoining channels, but these sub-channels are generally smaller, shorter and more numerous, often with no obvious dominant channel.

Step 2: After classifying channel pattern, determine whether the channel is constrained within a narrow valley, constrained by local features within a broad valley, unconstrained and free to move about within a broad flood plain, or free to move about, but within a relatively narrow valley floor.

Step 3: Then examine the channel to ascertain the bank and valley features that constrain the stream. Entry choices for the type of constraining features are bedrock, hillslopes, terraces/alluvial fans, and human use (e.g. road, dike, landfill, riprap, etc.).

Step 4: Based on your determinations from Steps 1 through 3, select and record one of the constraint classes shown on the Channel Constraint Form.

Step 5: Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels this is 0%). Record this value on the Channel Constraint Form.

Step 6: Finally, measure the typical channel width and visually estimate the average width of the valley floor. Record these values on the Channel Constraint Form.

Step 7: Measure the height and length of the constraining feature treated by the restoration project.

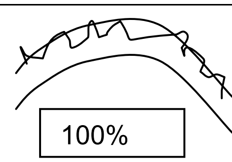
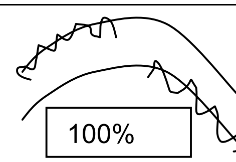
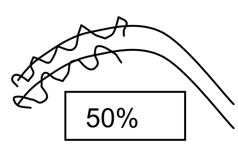
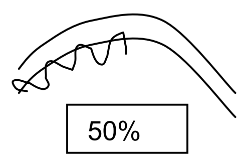
<table>
<tr><td colspan="2">Site ID:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Channel Pattern (Check one)</td><td></td><td></td></tr>
<tr><td colspan="4">❑ One channel
❑ Anastomosing channel – relatively long major and minor channels branching and rejoining
❑ Braided channel – multiple short channels branching and rejoining – mainly one channel broken up by numerous mid channel bars.</td></tr>
<tr><td colspan="2">Channel Constraint (Check one)</td><td></td><td></td></tr>
<tr><td colspan="4">❑ Channel very constrained in a V-shape valley (i.e. it is very unlikely to spread out over the valley or erode a new channel during a flood).
❑ Channel is in broad valley but channel movement by erosion during floods is constrained by incision (flood flows do not commonly spread over valley floor or into multiple channels).
❑ Channel is in narrow valley and is not very constrained, but limited in movement by relatively narrow valley floor (< 10X bankfull width).
❑ Channel is unconstrained in broad valley (i.e. during flood it can fill off channel areas and side channels, spread out over flood plain, or easily cut new channels by erosion.</td></tr>
<tr><td colspan="2">Constraining Features (Check one)</td><td></td><td></td></tr>
<tr><td colspan="4">❑ Bedrock (i.e. channel is a bedrock dominated gorge)
❑ Hillslope (i.e. channel constrained in a narrow V-shape valley)
❑ Terrace (i.e. channel is constrained by its own incision into river/stream gravel/soil deposits)
❑ Human bank alterations (i.e. constrained by rip-rap, landfill, dike, road, etc.)
❑ No constraining features</td></tr>
<tr><td colspan="2">Percent of channel length with margin in contact with constraining feature. _______%</td><td colspan="2">Percent of channel margins Examples</td></tr>
<tr><td colspan="2">Bankfull width: ____________meters</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Valley width (Visual estimated average) Note: Be sure to include distances between both sides of valley border for valley width ____________m</td><td>
</td><td>
</td></tr>
<tr><td colspan="4">Comments</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
</table>

Figure 3. Channel Constraint Form

METHOD FOR CHARACTERIZING STREAM MORPHOLOGY, THALWEG PROFILE

Protocol taken from*: Peck et al. (Unpubl.), Table 7-3; Kauffman et al. (1999)*

PURPOSE

The Thalweg profile can detect changes in the stream morphology associated with habitat restoration projects designed to improve pool-riffle relationships, provide velocity changes and other structure beneficial as hiding and holding habitat for salmonids.

EQUIPMENT

Surveyor's telescoping rod, 50 m measuring tape, laser range finder, camera tripod, 2 - ½ in. diameter PVC pipe, 2-3 m long, meter stick, surveyor tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

SITE SELECTION

The sample reaches are those laid out on page 9.

SAMPLING DURATION

Sampling should occur during summer low flow.

PROCEDURE

The Thalweg Profile is a longitudinal survey of depth, habitat class, presence of soft/small sediment deposits, and off-channel habitat at 100 equally spaced intervals (150 in streams less than 2.5 m wide) along the centerline between the two ends of the sampling reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. Wetted width is measured and substrate size is evaluated at 21 equally spaced cross-sections (at 11 regular Transects A through K plus 10 supplemental cross-sections spaced mid-way between each of these).

Step 1: Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach. For widths < 2.5 m, establish stations every 1 m. For widths between 2.5 and 3.5 m, establish stations every 1.5 m. For widths > 3.5 m, establish stations at increments equal to 0.01 times the sampling reach length.

Step 2: Complete the header information on the Thalweg Profile and Woody Debris Form, noting the transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the "INCREMENT" field on the field data form.

NOTE: *If a side channel is present and contains between 16 and 49% of the total flow, establish secondary cross-section transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary transect by checking both "X" and the associated primary transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.*

Step 3: Begin at the downstream end (station "0") of the first transect (Transect "A").

Step 4: Measure the wetted width if you are at station "0", station "5" (if the stream width defining the reach length is 2.5 m), or station "7" (if the stream width defining the reach length is < 2.5 m). Wetted width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m for widths up to about 3 meters, and to the nearest 5% for widths > 3 m. This is 0.2 m for widths of 4 to 6 m, 0.3 m for widths of 7 to 8 m, and 0.5 m for widths of 9 or 10 m, and so on. For dry and intermittent streams, where no water is in the channel, record zero for wetted width.

NOTE: *If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.*

Step 5: At station "5" or "7" (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form.

Step 6: At each Thalweg Profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the "thalweg"), which may not always be located at mid-channel. Measure the thalweg depth to the nearest cm, and record it on the Thalweg Profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

NOTE: *For dry and intermittent streams where no water is in the channel, record zeros for depth.*

Table 1. Thalweg channel and pool codes

POOL FORMING CODES		**CHANNEL UNIT CODES**	
N	Not a pool	PP	Pool, Plunge
W	Large Woody Debris	PT	Pool, Trench
R	Rootwad	PL	Pool, Lateral Scour
B	Boulder or Bedrock	PB	Pool, Backwater
F	Unknown, Fluvial	PD	Pool, Impoundment
		GL	Glide
	Combinations eg. WR, BR, WRB	RI	Riffle
		RA	Rapid
		CA	Cascade
		FA	Falls
		DR	Dry Channel

NOTE: *At stations where the thalweg is too deep to measure directly, stand in shallower water and extend the surveyor's rod, calibrated rod, or pole at an angle to reach the thalweg. Determine the rod angle by resting the laser range finder on the upper surface of the rod and reading the angle on the external scale of the laser range finder. Leave the depth reading for the station blank, and record a "U" flag. Record the water level on the rod and the rod angle in the comments section of the field data form. For even deeper depths, it is possible to use the same procedure with a taut string as the measuring device. Tie a weight to one end of a length of string or fishing line and then toss the weight into the deepest channel location. Draw the string up tight and measure the length of the line that is under water. Measure the string angle with the laser range finder exactly as done for the surveyor's rod.*

Step 7: At the point where the thalweg depth is determined, observe whether unconsolidated, loose ("soft") deposits of small diameter (<16mm), sediments are present directly beneath your ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by "feeling" the bottom with the staff. Record presence or absence in the "SOFT/SMALL SEDIMENT" field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comments section of the field form when determining substrate size and type.

Step 8: Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided. For dry and intermittent streams where no water is in the channel, record habitat type as dry channel (DR).

Step 9: If the station cross-section intersects a mid-channel bar, indicate the presence of the bar in the "BAR WIDTH" field on the field data form.

Step 10: Record the presence or absence of a side channel at the station's cross-section in the "SIDE CHANNEL" field on the field data form.

Step 11: Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the "BACKWATER" column of the field form.

Step 12: Proceed upstream to the next station and repeat Steps 4 through 11.

Step 13: Repeat Steps 4 through 12 until you reach the next transect. At this point, complete Channel/Riparian measurements at the new transect (Section 7.5). Then prepare a new Thalweg Profile and Woody Debris Form and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect "K").

THALWEG PROFILE FORM										
SITE NAME:						DATE:		VISIT: 1 2		
SITE ID:						TEAM ID:				
TRANSECT (X) A-B B-C C-D D-E E-F F-G G-H H-I I-J J-K										
THALWEG PROFILE							Increment (m) →			
Station	Thalweg Depth cm (XXX)	Wetted Width (XX.X)	Bar Width Y/N	Bar Width (XX.X)	Soft/Small sediment (X for yes)	Channel Unit Code	Pool Form Code	Side Channel (X for yes)	Flag	Comments
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
TOTAL										
MEAN										
VAR										
SE										

Figure 3. Thalweg Profile Form

METHOD FOR MEASURING RESIDUAL DEPTH

Protocol taken from: ***Peck et al. (Unpubl.), Table 7-6; Kauffman et al. (1999)***

PURPOSE

Using the following methods, the water surface slope and bearing can be determined. These measures can be used to calculate residual pool depth. Residual pool volume is the amount of water that would remain in the pools if there were not flow and the pools were impermeable basins. The intent of measuring this parameter is to show the changes in cross sectional stream complexity typified by pools and riffles.

Slope and bearing are measured using two people by back-sighting downstream between transects.

EQUIPMENT

Surveyor's telescoping stadia rod, 50 m measuring tape, laser range finder, camera tripod, 2 – ½ in diameter PVC pipe, 2-3 m long, surveyor flagging tape, Bearing compass, fisherman's vest with lots of pockets, chest waders, appropriate waterproof forms.

PROCEDURE

Step 1: Stand in the center of the channel at the downstream cross-section transect. Determine if you can see the center of the channel at the next cross-section transect upstream without sighting across land (i.e. do not short circuit a meander bend). If not, you will have to take supplementary slope and bearing measurements.

Step 2: Set up a tripod in shallow water or have one person hold a **stadia rod** at the downstream cross-section transect (or at a supplemental point). Standing tall in a position with your feet as near as possible to the water surface elevation, set the **tripod** extension and mark it with a piece of **flagging tape** at your eye level. Remember the depth of water in which you are standing when you adjust the flagging to eye level.

Step 3: Walk upstream to the next cross-section transect. Find a place to stand at the upstream transect that is at the same depth as where you stood at the downstream transect when you set up the eye level flagging.

Step 4: With the **laser range finder**, site back downstream on your flagging at the downstream transect. Read and record the percent slope in the "MAIN" section on the **Slope and Bearing Form**. Record the "PROPORTION" as 100%.

Step 5: Stand in the middle of the channel at upstream transect, and site back with your **compass** to the middle of the channel at the downstream transect. Record the bearing (degrees) in the "MAIN" section of the Slope and Bearing Form.

Step 6: Retrieve the tripod from the downstream cross-section station and setup at the next upstream transect as described in Step 2.

Step 7: When you get to each new cross-section transect, backsight on the previous transect. Repeat steps 2 through 6 above.

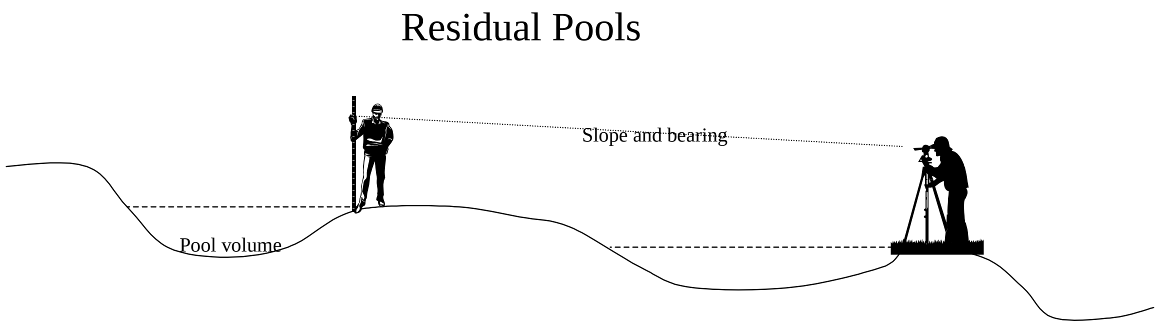


Figure 4. Residual Pools

Project No:		Con/Impact		Sample Year		Date:		Stream	
TRANSECT	MAIN			1ST SUPPLEMENTAL			2ND SUPPLEMENTAL			FLAG
	SLOPE XX.X %	BEARING 0-359	BEARING 0-359	SLOPE XX.X %	BEARING 0-359	BEARING 0-359	SLOPE XX.X %	BEARING 0-359	BEARING 0-359	
A > B										
B > C										
C > D										
D > E										
E > F										
F > G										
G > H										
H > I										
I > J										
J > K										

FLAG	COMMENTS

Figure 5. Form for recording residual pool data.

TESTING FOR SIGNIFICANCE

We can create a table resembling the following from the data collected for each of the indicators for vertical profile area, mean residual depth, and channel constraints.

Among all of the measures taken in a Thalweg Profile, two measures demonstrate the greatest precision and signal to noise ratio (see Table 3). These are the mean residual Thalweg depth and the residual pool vertical profile area. We wish to test whether the mean residual pool vertical profile area (the cross-sectional area of water that would be contained in pools if no water were flowing) has increased significantly post impact.

The data will be tested using a paired *t*-test. The paired *t*-test is a very powerful test for detecting change because it eliminates the variability associated with individual sites by comparing each stream to itself, that is, at upstream and downstream locations within the same stream. The impact reach and control reach for each stream are affected by the same local environmental factors and local characteristics in the size and depth of pools and riffles in contrast with other stream systems with their own unique environmental conditions. In other words, the two observations of the pair are related to each other.

Because the paired *t*-test is such a powerful test for detecting differences, very small differences may be statistically significant but not biologically meaningful. For this reason, biological significance will be defined as a 20% increase in mean residual depth and residual pool profile area at the impact sites. The statistical test will be one-sided for an Alpha=0.10. We use a one-sided test because a significant decrease in pool area or depth after the impact would not be considered significant, that is, the project would not be considered effective. Therefore, we are not interested in testing for that outcome. The test will be conducted in Years 1, 3, 5, and 10. If the results are significant in any of those years, the channel constraint projects will be considered effective.

Our conclusions are, therefore, based upon the differences of the paired scores for the two (four after completing two replicates) sampled instream structure projects. Though somewhat confusing, it may be helpful to think of the statistic as the “difference of the differences”. A one-tailed paired-sample *t*-test would test the hypothesis:

H_0 : The mean difference is less than or equal to zero.
H_A : The mean difference is greater than zero.

The test statistic is calculated as:

$$t_{n-1} = \frac{đ - 0}{S_{đ}}$$

where
$\underline{đ}$ = mean of the differences for Year 0 and a subsequent year

$S_{đ}$ = variance of the differences

$S_{đ} = S_d / n^{1/2}$ = variance mean

n = number of sites (or site pairs).

Table 3. Composite Thalweg variables exhibiting the best all around precision and signal to noise ratios. RMSE = σ_{rep} is the root mean square error. The lower the value, the more precise the measurement. CV σ_{rep} / ”(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$ is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in single or multiple sites. Data taken from Kauffmann et al. (1999). This table is provided for information purposes only.

Variable	Description	RMSE = σ_{rep}	CV = σ_{rep} / ”(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
AREASUM	Residual Pool vertical Profile Area (m^2/reach	7.6	25	17
RP100	Mean residual depth for 100 data points m^2/100 m =cm	2.2	19	9

DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from the project will be entered into the PRISM database after each sampling season. The PRISM database contains data fields for the following parameters associated with these objectives.

Table 3. PRISM data requirements for instream artificial structure habitat projects.

Indicator	Metric	Pre impact Year 0	Post impact Year 1	Post impact Year 3	Post impact Year 5	Post impact Year 10
Dike removed/set back by project	miles	√				
Channel capacity	% change	√	√	√	√	√
Level 1 effective	Yes/No		√	√	√	√
Thalweg Profile impact	Mean Residual pool vertical area Mean Stream residual depth	√	√	√	√	√
Thalweg Profile control	Mean Residual pool vertical area Mean Stream residual depth	√	√	√	√	√
Level 2 effective	Yes/No		√	√	√	√

REPORTS

PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season for Years 1, 3, and 5.

FINAL REPORT

A final report will be presented to the SRFB in writing after the sampling season for Year 10. It shall include:

- Estimates of precision and variance.
- Confidence limits for data.
- Summarized data required for PRISM database by project.
- Determination whether project met decision criteria for effectiveness.
- Analysis of completeness of data, sources of bias.

Results will be reported to the SRFB during a regular meeting after 1, 3, 5, and 10 years post project. Results will be entered in the PRISM database and will be reported and available over the Interagency Committee for Outdoor Recreation website and the Natural Resources Data Portal.

ESTIMATED COST

It is estimated that approximately 20 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of $2,300-$3,600 per project.

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